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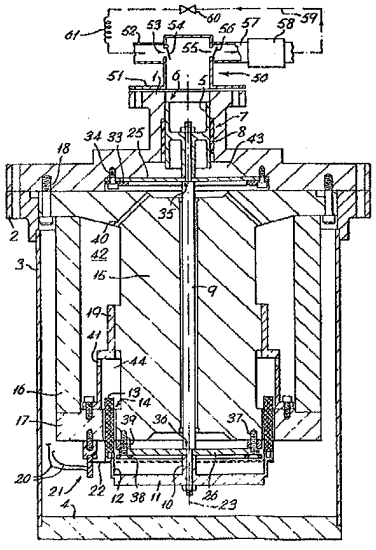
(54) Support system for a reciprocating compressor piston.

(57) A compressor piston (5) reciprocates with small clearance in its cylinder (6) and is driven electromagnetically (13–22). Axial alignment of the piston (5) is maintained by mounting the piston rod (9) on two axially-spaced springs (25), (26) that are relatively flexible axially but stiff radially. The springs (25, 26) may be formed by cutting thin metal discs to spiral form, and an individual spring (25, 26) may comprise a stack of such spirals (27) prevented from interference with each other by spacers (28, 29).



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IMPROVEMENTS IN OR RELATING TO COMPRESSORS AND REFRIGERATION PLANT

This invention relates to compressors, and especially to compressors for use in refrigeration equipment. In the fields of both commerce and scientific research, there is a growing need for compressors that can be relied upon to run for long periods - say a year or more - without maintenance, and in particular without lubrication. In commerce, for example, such compressors are needed for long-running refrigeration plants used for the freeze-drying of merchandise or for the temperature control of super-conducting electronic equipment, while in the field of research such compressors are needed for example for refrigerators used in specimen cooling in electron microscopes, the cooling of single crystals and the collection of atmospheric pollutamts.

The present invention arises from our appreciation of the advantages of using a piston that runs with clearance within a cylinder, and hence with no wear, and of the potential of a particularly simple support system to hold the piston to a constant path of travel. According to our invention a compressor comprises a driven piston adapted to reciprocate in straight-line motion within a cylinder with small clearance, and in which alignment of the movement of the piston is obtained by supporting it at two axially-spaced locations by support members that are very stiff in a radial direction but comparatively flexible axially.

The support members may constitute springs and may comprise thin discs that have been cut to form spirals and that are fixed concentrically to the piston rod so as to lie in a plane normal to its axis. Preferably the spirals are of at least three starts. The discs are preferably made from materials such as phospor bronze or beryllium-copper. A form of spring specially preferred comprises a stack of such cut discs, each disc being separated from the next by spacers so that the spirals of adjacent discs do not touch or otherwise interfere as the piston rod reciprocates.

The piston may be of hard material and the cylinder wall may have a soft lining, preferably of lead/PTFE or some other material that redistributes during wear but does not readily break up into debris. On assembly, the piston may make a light interference fit with the lining but may then by wear redistribute the material of the lining to create the clearance.

The piston may be driven electromagnetically, for instance by a drive comprising an energised coil attached to the piston rod and moving within magnetic pole pieces secured to the compressor housing.

The invention also includes refrigeration plant including such a compressor. Where such a plant comprises a simple compression chamber, the piston may communicate directly with that chamber. In more complex plant the piston may perform the first of a number of stages of a cooling operation or cycle: for instance the piston may serve as the compression piston in a Stirling refrigerator, and a second (displacer) piston will also be required to move in step but with a certain difference of phase to move the compressed gas continuously as the Stirling cycle proceeds.

The invention is further stated by the claims at the end of this specification and will now be described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 shows refrigeration plant in outline and an axial section through a compressor;

Figure 2 is a plan view of a support member, and

Figure 3 is a section on the line III-III in Figure 2.

Figure 1 shows a compressor housing comprising a top plate 1, flanged ring 2, side wall 3 and base plate 4. A stainless steel piston 5 moves within a cylindrical bore 6 in top plate 1; the walls of this bore are formed with a recess 7 in which fits a lead/PTFE liner 8. The head of piston 5 is attached to one end of a piston rod 9, the other end of which is attached to the central boss 10 of a plate 11 having a peripheral flange 12. An electromagnetic coil 13 is mounted on flange 12 so as to lie in the air

gap 14 of a magnetic circuit comprising an iron yoke 15, a permanent magnet 16 and an iron pole-piece 17. Yoke 15 is supported from top plate 1 by bolts 18, and magnet 16 and pole-piece 17 are in turn supported from yoke 15 by a non-magnetic stepped collar 19. Electric current reaches coil 13 from a suitable source (not shown) by means of leads 20, insulated terminal blocks 21 mounted on pole-piece 17, and conducting springs 22 which connect blocks 21 with coil 13.

The supply of alternating electric current to coil 13 causes the coil, and thus the attached rod 9 and piston 5, to reciprocate in a direction parallel to the axis 23 of the rod. The location of this axis is maintained constant by means of two resilient support members 25, 26. Each of these members, as Figures 2 and 3 show best, comprises a stack of flat spiral springs 27 in which adjacent springs are separated from each other at the periphery and at the axis by spacer rings 28, 29 respectively. The number of springs in each of the two members 25, 26 may be different, reflecting different loadings at opposite ends of rod 9. Each spring comprises a thin metal disc, of phosphor bronze or beryllium-copper for instance, in which grooves 30 have been formed, by photo-etching for instance, to make a three-start spiral. As Figure 2 shows best, the plan width of each spiral leaf is greater at the two extremities (31) than in the middle (32), to create great axial flexibility in the spiral and to produce an approximately constant radius of curvature along the leaf and hence to distribute stresses equally along the leaf. The periphery of resilient member 25 is secured to top plate 1 by a clamping ring 33 and bolts 34, and the centre of the member is gripped between the central boss of piston 5 and a shoulder 35 on rod 9. The centre of member 26 is gripped between boss 10 of plate 11 and a shoulder 36 on rod 9, and the periphery of the system is anchored to yoke 15 by bolts 37 and a clamping ring 38, with a spacer ring 39 intervening.

Members 25, 26 act as springs that are very flexible in the axial direction, but very stiff radially. While permitting sufficient axial displacement, the maximum stress can be kept below the fatigue limit of the material and so give effectively infinite fatigue life. Thus they maintain the location of axis 23 accurately constant, while allowing piston 5 and rod 9 to reciprocate readily in response to the electromagnetic drive. Breather passages 40, 41 allow ready movement of gas between the comparatively large gas space 42 and the relatively smaller spaces 43, 44, where the pumping action of piston 5 and coil 13 might set up undesirable forces in the absence of the communicating passages. Typically, the housing will be filled with a suitable gas (e.g. helium) under pressure.

While showing the piston 5 and other important parts of the compressor in detail, Figure 1 also shows in outline a refrigeration plant of which the compressor forms a part. Structure 50, including a plate 51 attached by bolts (not shown) to top plate 1, completes the enclosure of the cylinder in which piston 5 moves. If the refrigeration plant is of conventional kind, a suction stroke of piston 5 will cause refrigerant to enter the cylinder from conduit 52 by way of port 53 and non-return valve 54, and the subsequent compression stroke of the piston will then compress the charge of refrigerant and expel it from the cylinder by way of port 55 and non-return valve 56 into conduit 57, and thence to condenser 58 and so back to conduit 52 by way of the remainder (59) of the conventional refrigerant cycle including a throttle valve 60 and evaporator 61. The plant could however utilise a different refrigeration process, for instance one making use of the Stirling cycle, in which case the working fluid would essentially move back and forth rather than circulate and the cylinder would typically communicate by way of a single unvalved port with a conduit which would lead by way of a heat exchanger to the unit

generally known as a regenerator. The latter unit comprises a displacer piston which typically moves at the same frequency as but out-of-phase with piston 5.

In experiments a radial clearance of .0025 mm between a piston of 20 mm diameter and its surrounding cylinder has been found very satisfactory, permitting negligible leakage of gas past the piston even when the axial oscillation frequency of the piston falls as low as 5 Hz; a more typical frequency was 25 Hz for a 10 mm stroke. The simplicity of the suspension system of members 25, 26 readily allows rod 9 to be jigged into position so that piston 5 is located accurately with clearance within cylinder 6 from the start. Alternatively with piston 5, rod 9 and upper support member 25 assembled, the piston may be fitted into cylinder 6 (containing the lead/PTFE insert 8) as a light push fit with no play. Support member 25 may then be attached to top plate 1, yoke 15 and attached parts may then be secured to the same plate by the bolts 18, and member 26 may then be secured to rod 9 and yoke 15 and the electromagnetic drive connected and set into operation. During such operation liner 8 wears by redistribution of the material within it, rather than by production of debris, until a true clearance fit is obtained.

Such a compressor, driven by a 60 watt source of electrical power, provided enough power to produce say 1 watt at 80K using a Stirling cycle or similar machine, for instance a Gifford-McMahon or pulse tube type refrigerator, for which the compressor is well suited to produce the necessary gas pressure variations because it suffers no contamination from lubricants etc. or wear products.

CLAIMS

1. A compressor comprising a driven piston (5) adapted to reciprocate in straight-line motion within a cylinder (6) with small clearance, characterised in that alignment of the movement of the piston is obtained by supporting it at two axially-spaced locations by resilient support members (25, 26) that are stiff in a radial direction but comparatively flexible axially.

2. A compressor according to Claim 1, characterised in that the support members are in the form of spirals fixed concentrically to the piston rod (9) so as to lie in a plane normal to its axis.

3. A compressor according to Claim 2, characterised in that the spirals are of at least three starts.

4. A compressor according to Claim 2 characterised in that the support members comprise thin discs that have been cut to spiral form.

5. A compressor according to Claim 2, characterised in that at least one of the support members comprises a stack of such spirals, each spiral being separated from the next by spacers (28, 29) so that adjacent spirals do not touch or otherwise interfere with each other as the piston rod reciprocates.

6. A compressor according to Claim 1, characterised in that the piston is of hard material and the wall of the cylinder has a soft lining (8) of a kind that redistributes during wear but does not readily break up into debris.

7. A compressor according to Claim 6, characterised in that on assembly the piston makes a light interference fit with the lining so as then by wear to redistribute the material of the lining to create the clearance.

8. A compressor according to Claim 1, characterised in that the piston is driven electromagnetically.

9. Refrigeration plant including a compressor, characterised in that the compressor is as claimed in Claim 1.

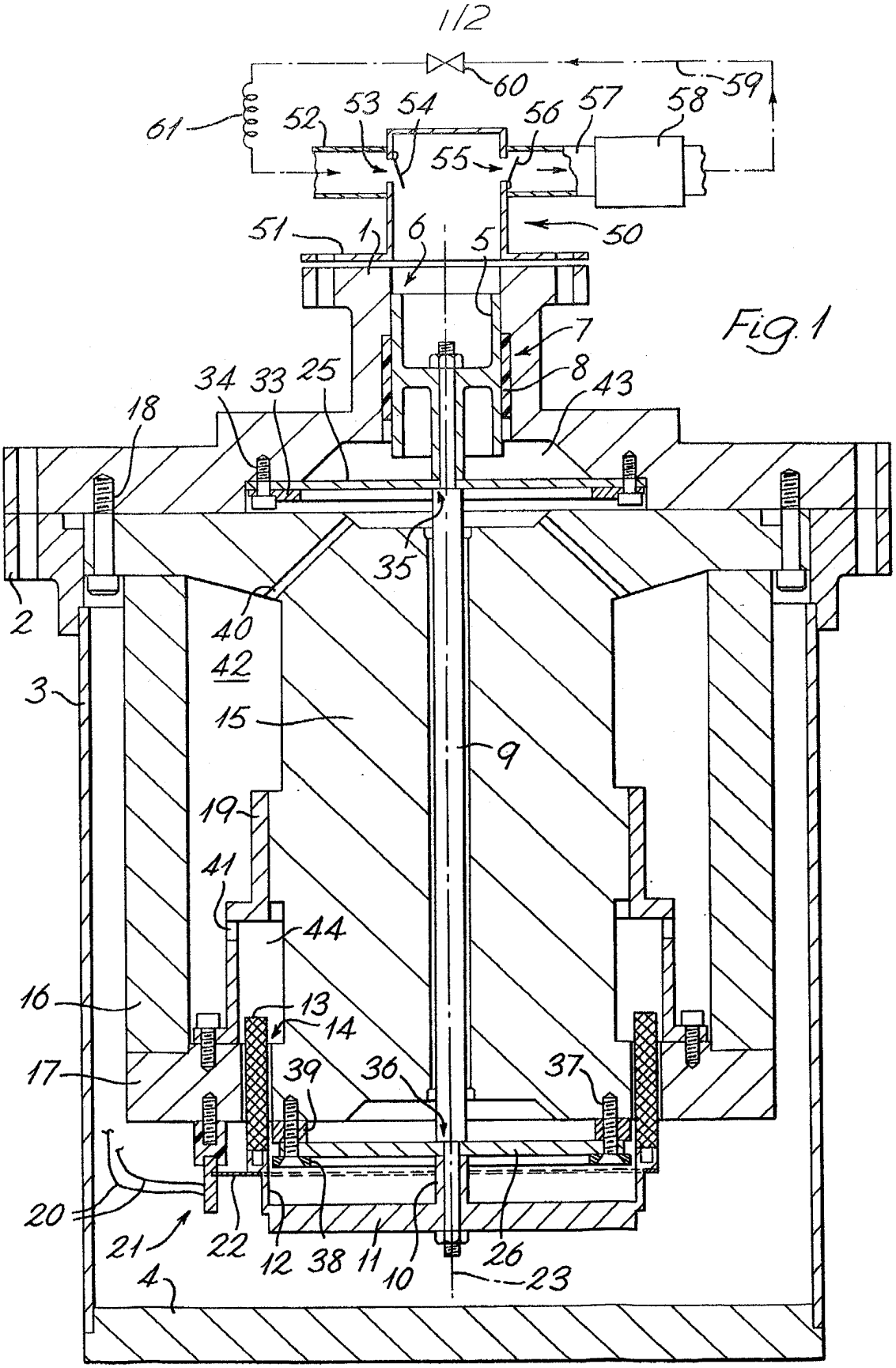
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Fig. 1

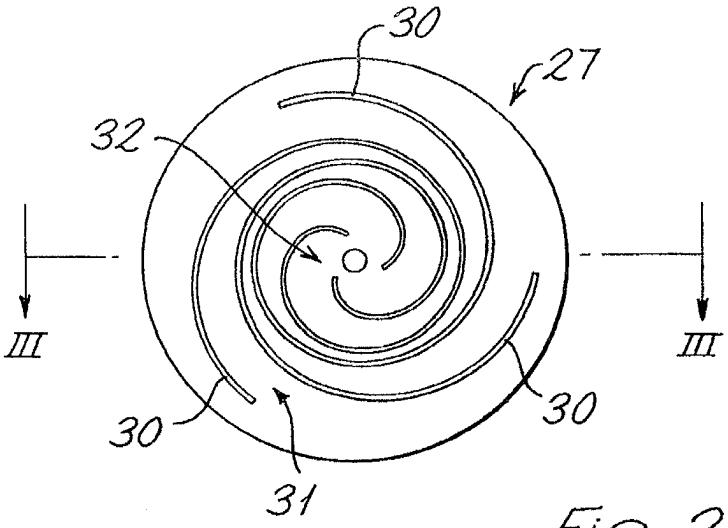

Fig. 2

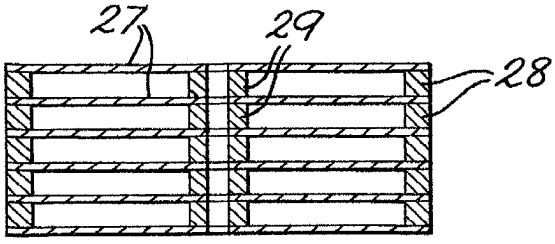

Fig. 3

European Patent Office

EUROPEAN SEARCH REPORT

0028144
Application number
EP 80 30 3780

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
X	FR - A - 1 069 802 (ROULEMENTS A BILLES) * Page 1, left-hand column, paragraphs 8-14; right-hand column, paragraphs 1-3; figures 1,2 *	1,4,8
X	FR - A - 1 550 579 (PHILIPS) * Page 1, left-hand column, paragraph 1; page 2, right-hand column, paragraphs 1-3; figures 1-3 *	1-5,8,9
	FR - A - 1 151 453 (BERGER) * Page 2, right-hand column, paragraph 3; figure 1 *	6,8
	US - A - 3 958 841 (BRAUN) * Column 1, lines 65-69; column 2, lines 1-2; figure 1 *	6
	US - A - 3 185 487 (HEASSLER) * Column 1, lines 41-47; column 2, lines 35-46; figure 1 *	6,7
A	US - A - 3 325 085 (GAUS) * In its entirety *	
A	US - A - 2 198 506 (REPLOGLE) * In its entirety *	

CLASSIFICATION OF THE APPLICATION (Int. Cl.³)

F 04 B 35/04
39/04

TECHNICAL FIELDS SEARCHED (Int. Cl.³)

F 04 B

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	02-02-1981	HEINLEIN

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